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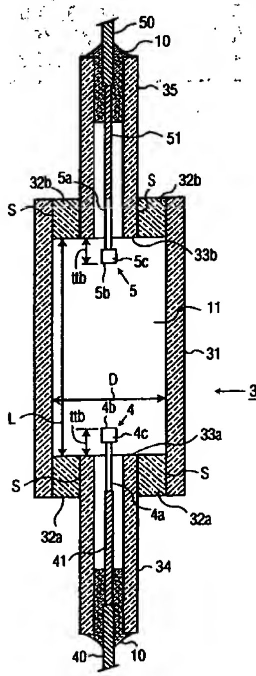
(54) Title: CERAMIC METAL HALIDE LAMP



(57) Abstract: A metal halide lamp has a ceramic discharge vessel (3) with an inside length L, an inside diameter D, and an aspect ratio L/D of between 3 and 5. The filling includes xenon, mercury, sodium halide, and halides of rare earth metals. Hydrogen iodide voltage spikes during start-up are related to product of volume and the cold xenon pressure, which are adjusted to limit the spikes. Voltage crest factor is related to the product of total operating pressure and the square of the inside diameter, which are adjusted to limit the crest factor. The ceramic discharge metal halide (CDM)lamp may have a power rating of 200 W or more and can be used with an existing ballast for a high pressure sodium (HPS) lamp of like power rating.

WO 01/69650 A1

Ceramic metal halide lamp

The present invention relates to a ceramic metal halide lamp having a ceramic discharge vessel enclosing a discharge space having a length L, a diameter D, and an aspect ratio L/D; a fill gas including xenon, mercury, sodium halide, and halides of rare earth metals; and a pair of electrodes for maintaining a discharge in the fill gas.

High wattage (over 150 W) metal halide lamps are presently available only with quartz discharge vessels, which are larger than ceramic vessels and have a lower (-200°C) maximum allowable wall temperature. A smaller vessel is desirable because the smaller discharge vessel better approximates a point source. Higher temperatures are desirable to achieve a higher cold spot temperature T_C on the vessel wall; this increases the vapor pressure of the salts in the fill gas. The term "ceramic" as used herein means metal oxide, such as sapphire or polycrystalline alumina (PCA), as well as nitrides such as AlN.

U.S. Patent No. 5,973,453 discloses a ceramic discharge metal halide (CDM) lamp wherein EA/D>5, EA being the distance between electrode tips, the tips being spaced from the endwalls of the discharge space. The ionizable filling includes Xe as an ignition gas, and NaI and CeI_3 in a molar ratio between 3:1 and 7:1. In an embodiment having a rated power of 150 W and intended as a retrofit for a high pressure sodium installation operating at 80-100 volts, EA/D=8, the fill includes Hg, and the Xe fill pressure is 250 mbar (187 torr). This yields a color rendering index (CRI) of 58 at a color temperature of 3900°K, and a luminous efficacy of 130 lm/W. It is noted that a comparable HPS lamp has a lower luminous efficacy (110 lm/W) and considerably lower CRI (21), while a comparable high pressure mercury lamp has comparable CRI but much lower efficacy (60 lm/W).

In another 150 W embodiment disclosed in U.S. 5,973,453, the fill is free of mercury and the lamp is operated at 45 V, so it is not suited as a retrofit for HPS. The Xe fill pressure is 1250 mbar (938 torr), the efficacy is 145 lm/W, and the CRI is 53. In a 185 W embodiment, the lamp voltage is 53 V, the Xe fill pressure is 500 mbar (375 torr), and the CRI is 61. All embodiments use a ceramic tube with a wall thickness of 1.4 mm. All Hg-free embodiments are operated on a square wave voltage generated by an electronic ballast.

While U.S. 5,973,453 discloses a CDM lamp with high efficacy, and even suggests a possible retrofit for an HPS ballast, the color rendering is still less than desirable and would not be suitable for many applications.

U.S. Patent No. 6,031,332 discloses a CDM lamp having a CRI over 90, and achieves a limited voltage crest factor, so that the lamp achieves a long useful life. Voltage crest factor V_{CF} is the ratio of the reignition voltage to the arc voltage, i.e. the operating voltage. The reignition voltage is the voltage required to reignite the discharge when it extinguishes as the polarity of an AC supply voltage changes. V_{CF} assumes a high value in particular when the lamp is operated on a sinusoidal voltage, which is typical of a magnetic ballast, and usually increases during lamp life.

U.S. 6,031,332 addresses the problem of increasing reignition voltage by including calcium iodide in the fill to a molar quantity of 30 to 50% of the total molar quantity of halides. The ratio EA/D is less than 1.0 and L/D is slightly greater than 1.0; the fill includes argon at a pressure of 140 mbar (105 torr) as the ignition gas. The lamp operates at 80 to 100 V but the power is only 70 W; as such it would not be suitable for retrofit in an HPS installation.

A well known problem in metal halide lamps is the occurrence of hydrogen iodide voltage spikes. HI spikes occur during run-up of metal halide lamps that have hydrogen contamination in the presence of free iodide. Typically, the hydrogen comes from water that is present in the fill gas, but it can also be present on the lamp parts and the salts. Special precautions are required to insure that the H_20 level inside the arc tube is as low as possible, preferably less than 0.5% of the fill gas.

One method to eliminate the HI spikes is given in U.S. 4,409,517, which discloses the use of Nb as a window to allow the rapid diffusion of H_2 out of the arc tube. U.S. 4,203,049 discloses a getter for the hydrogen.

The prior art does not disclose a high wattage CDM lamp with good color rendering, high efficacy, and high lumen maintenance which would be suitable for use with an existing magnetic ballast for an HPS lamp.

Throughout this specification and claims, D, EA and L are expressed in mm, except where explicitly stated otherwise.

It is a primary object of the invention to provide a high wattage (over 150 W) CDM lamp which can be used with a magnetic ballast which was designed for use with a

high pressure sodium (HPS) lamp. It is a related object to provide a CDM lamp which limits hydrogen iodide voltage spikes so they are within the voltage supplied by the ballast.

It is a further object to provide a CDM lamp which has a low voltage crest factor so that flicker is eliminated and long life is achieved using an HPS ballast.

It is a further object to determine a design space for the lamp that is within established material limits while providing the desired lamp efficacy and color properties.

These and other objects are achieved in a CDM lamp using xenon as a starting gas and having an aspect ratio in the range of 3 to 5. This is considered a medium aspect ratio, since most prior art CDM lamps have aspect ratios of about 1, and HPS lamps have aspect ratios on the order of 10.

The design space was determined by the use of designed experiments and the characteristic equations for each design parameter. Figure 3 shows the design space that was found for a 200 W CDM lamp. Four curves were plotted. The curve 100 on the lower left represents a voltage crest factor V_{CF} of 1.7, and the space above it represents lower V_{CF}'s. This is desirable because ballasts for HPS lamps have low sustaining voltages. The next curve 200 represents a wall temperature T_W of 1250°C, and the space above it represents lower wall temperatures. This is desirable because at higher temperatures the PCA is attacked by the salts and also evaporates, which darkens the outer envelope and shortens lamp life. Next are two intersecting curves 300, 400 which define the actual design space 500. One is the curve 300 for a cold spot temperature of 1005°C; the space above it represents lower temperatures. The other curve 400 represents an efficacy of 90 lm/W; the space below it represents higher efficacies. The design space is limited by an inside diameter P of 6.7 mm and a length L of 33 mm (aspect ratio 4.9), and, at a diameter D of 8 mm, lengths L of 25 mm (aspect ratio 3.1) and 30 mm (aspect ratio 3.8).

The design space for the discharge tube is also limited by the need to reduce or eliminate hydrogen iodide voltage spikes. It was found that the level of HI spike voltage during the first run-up of the lamp is dependent on both the volume V of the arc tube and the cold fill pressure P of the rare gas. In a series of experiments with Xe as the gas, the minimum HI spike voltage was measured and plotted against the product of P and the volume V, as shown in Figure 4. A curve C fit to the data is described by the equation $V_{HI} = 33654 (PV)^{-1.185}$, where P is in torr and V is in cubic centimeters (cm^3). To minimize H_2 and H_20 in these experiments, the arc tubes were made in an inert gas atmosphere dry box, the discharge tube was vacuum baked at 1300° for one hour, the electrodes were vacuum baked at elevated temperature, and the salts were contained in an inert gas atmosphere until dosed into the arc

tube. In spite of these careful steps, HI spikes still form, but can be controlled by choice of P and V.

For a lamp to sustain on a ballast, the voltage spike must be below the available voltage supplied by the ballast. This voltage is typically 200 volts or more for lamps whose nominal lamp voltages are over 90 volts. The spike voltage should be less than 180 volts and practically less than 150 volts and preferably less than 100 volts for reliable starting. Plugging these voltages into the fitted equation, or reading the plot of Figure 4, yields the following results: PV = 82.7 torr-cm^3 for 180 volt spike; PV = 96.4 torr-cm^3 for 150 volt spike; PV = 135.8 torr-cm^3 for 100 volt spike.

The design space for the discharge tube is further limited by the need to limit the voltage crest factor V_{CF}. It has been found that V_{CF} of a new CDM lamp follows a curve d that is inversely proportional to the product of the total pressure P_{TOT} and the square of the inner diameter, as shown in Figure 5. The equation for the curve d is $V_{CF} = 39616/P_{TOT}D^2 + 1.359$, P_{TOT} in torr. In order for the lamp to run on existing HPS or other types of ballasts, to prevent flicker, and to promote long lamp life, V_{CF} should be less than 1.7. Lamps will achieve a V_{CF} of less than 1.7 if $P_{TOT}\,D^2 > 1.16 \times 10^5$ torr-mm^2. The total pressure can be calculated from the Hg dose (Hg) and arc tube volume V; assuming a parabolic temperature profile, the total pressure is $P_{TOT} = 748\,(Hg)/V + 8.87\,P$, where 748 has the units cm^3-torr/mg, (Hg) is the Hg dose in mg, V is in cm^3, and P is in torr. The last two equations can be designed to get a requirement for low V_{CF} in terms of construction parameters:

$$9.524 \times 10^5\,(Hg)/L + 8.87 D^2 P > 1.16 \times 10^5.$$

The data points in Figure 5 are from lamps operated on CWA (constant wattage autotransformer) ballasts. The total pressures were calculated from known Hg doses, Xe fill pressures, and arc tube volumes.

The advantages of the CDM lamp according to the invention are that it provides a high efficacy (over 90 lm/W), white light (~4000°K CCT, MPCD +/-10), and a high CRI (over 85) in a 200 W lamp. CCT is the correlated color temperature and MPCD is the minimum perceptible color difference, a measure of the color point from the black body line. The lamp also exhibits color stability and lamp-to-lamp color uniformity previously only enjoyed by lower wattage CDM lamps such as Mastercolor lamps (Mastercolor is a registered trademark of Philips Electronics North America Corporation). Additionally, the lamp is suitable as a retrofit for 200 W HPS S-66 ballasts.

Figure 1 is a diagrammatic elevation view of a lamp according t the invention;

Figure 2 is a diagrammatic axial section view of the discharge vessel in the lamp;

Figure 3 shows plots of diameter D vs. length L of a discharge vessel in a 200 W lamp, to achieve desired wall temperature, efficacy, voltage crest factor, and cold spot temperature;

Figure 4 shows a plot of hydrogen iodide spike voltage vs. PV;

Figure 5 shows a plot of voltage crest factor V_{CF} vs. $1/P_{TOT}D^2$;

Figure 6 is a table giving dimensions and performance parameters for three lamps according to the invention; and

Figures 7A -7D are schematics of known magnetic ballasts which can be used with the lamp according to the invention.

Figure 1 shows a metal halide discharge lamp according to the invention provided with a discharge vessel 3 having a ceramic wall which encloses a discharge space 11 containing an ionizable filling. Electrodes 4, 5 extend through plugs 34, 35 and receive current from conductors 8, 9 which also support the discharge vessel 3. The vessel 3 is surrounded by an outer bulb 1 which is provided with a lamp cap 2 at one end.

Figure 2 shows the discharge vessel 3 in greater detail. The vessel includes a cylindrical wall 31 extending between end walls 32a, 32b in which the ceramic projecting plugs 34, 35 are fitted; all joints S are sealed by sintering. The discharge space enclosed by the cylindrical wall has a diameter D, and a length extending between the end walls. The plugs 34, 35 receive current leads 40, 50 through ceramic melting joints 10, which provide a seal. The leads 40, 50 are niobium or other metal having a coefficient of expansion that corresponds to that of the end plugs 34, 35, and have halide resistant sleeves 41, 51, for example of $Mo\text{-}Al_2O_3$. Each of the electrodes includes a rod 4a, 5a connected to a respective lead, and a tip 4b, 5b fitted with a coil 4c, 5c. Each tip (4b,5b) extends above the respective end wall 32a,32b by a distance ttb.

The construction is described in greater detail in prior art patents such as U.S. 5,973,453 and U.S. 6,031,332. The present invention relates to the relationship between structural elements such as dimensions of the discharge vessel, total pressure exerted by the filling, and performance factors such as wall temperature, efficacy, and voltage crest factor.

According to a preferred embodiment of the CDM lamp according to the invention, the rated lamp power is 200 watts and the filling includes Xe with a cold fill pressure of 200 torr. Xenon is preferable to argon as an ignition gas because the atoms are larger and inhibit evaporation of the tungsten electrodes, so that the lamp lasts longer. The filling also includes Hg, NaI, and iodides of Tl, Dy, Ho, Tm, and Ca; the latter acts as a color adjuster.

The dimensions of the lamp and performance factors are summarized in the table of Figure 6; there are two examples of the 200 W lamp, and an example of a 400 W lamp. The discharge vessel of the latter has dimensions and Xe cold pressures such that hydrogen iodide voltage spikes and the voltage crest factor are minimized. This makes it possible to operate the lamp on an existing 400 W HPS (high pressure sodium) ballast, type S-51.

Figures 7A-7D are schematics of known ballasts with which the lamp according to the invention may be used. Fig. 7A shows a so-called "reactor ballast" which is common in Europe for low wattage (35-150 W) HPS lamps operating at 50 volts. In Europe, reactor ballasts are commonly used with a 230 volt supply voltage for all HPS lamp types with lamp voltages of about 100 volts. Figure 7B shows a constant wattage auto-transformer (CWA)-ballast which is commonly used for high wattage HPS lamps; this is the ballast for which the lamp according to the invention has been primarily designed, so that it can replace an HPS lamp without replacing the ballast. Figure 7C is a CWA-ballast commonly used for metal halide lamps. Both CWA-ballasts may be used with any line voltage, depending on where it is tapped. Figure 7D shows a magnetically regulated ballast for either HPS or metal halide. It is a pulse start ballast which provides excellent regulation but is large, heavy, and expensive, hence not common.

The foregoing is exemplary and not intended to limit the scope of the claims which follow.

CLAIMS:

1. Metal halide lamp comprising

a ceramic discharge vessel (3) enclosing a discharge space (11), having a length L, a diameter D, an aspect ratio L/D, and a volume,

a filling comprising xenon, mercury, sodium halide, and halide salts of metals selected from the group comprising Tl, Dy, Ho, Tm, and Ca , said xenon having a cold fill pressure P, said filling exerting during stable lamp operation an operating pressure P_{TOT}, and

a pair of electrodes (4,5) in said discharge space (11) for sustaining a discharge in said fill gas,

wherein said aspect ratio lies in a range from 3 to 5.

2. Metal halide lamp as in claim 1 wherein said lamp has a power rating of 200 watts, and wherein in a plot of L vs. D, the dimensions L, D are in mm and lie above a line defined by the points (32, 6.7) and (25, 8), and below a line defined by the points (32,6.7) and (30, 8).

3. Metal halide lamp as in claim 1 wherein the product PV is greater than 96.4 torr-cm^3, whereby hydrogen iodide spikes during start-up are limited to a maximum of 150 volts.

4. Metal halide lamp as in claim 3 wherein the product PV is greater than 136 torr-cm^3, whereby hydrogen iodide spikes during start-up are limited to a maximum of 100 volts.

5. Metal halide lamp as in claim 1 wherein the product $P_{TOT} \times D^2$ is greater than 1.16×10^5 Torr-mm^2 , whereby said lamp has a voltage crest factor which is less than 1.7.

6. Metal halide lamp as in claim 1 wherein said discharge vessel comprises a pair of opposed endwalls (32a, 32b) and a cylindrical wall (31) therebetween, said electrodes (4,5) extending from said endwalls by a distance of less than 4 mm.

7. Metal halide lamp as in claim 1 wherein said lamp has a power rating of 200 watts and said discharge vessel (3) has a wall thickness of less than 1.0 mm.

8. Metal halide lamp as in claim 1 wherein said gas fill consists essentially of xenon, mercury, sodium halide, and halide salts of metals selected from the group consisting essentially of Tl, Dy, Ho, Tm, and Ca.

9. Metal halide lamp as in claim 1 wherein said group further comprises Ce and Li.

10. Metal halide lamp as in claim 1 wherein said lamp has an operating voltage of 80 to 120 volts.

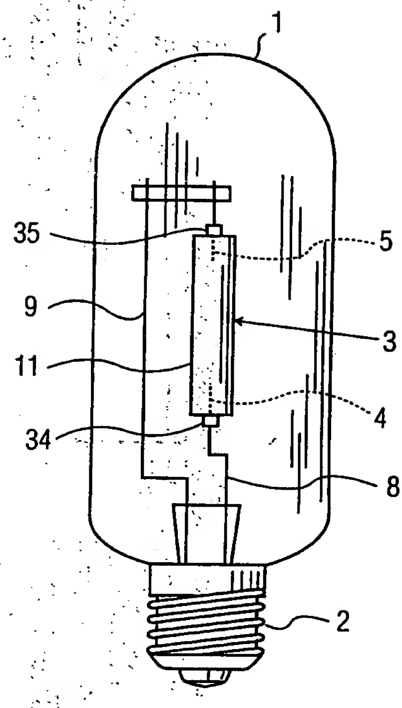
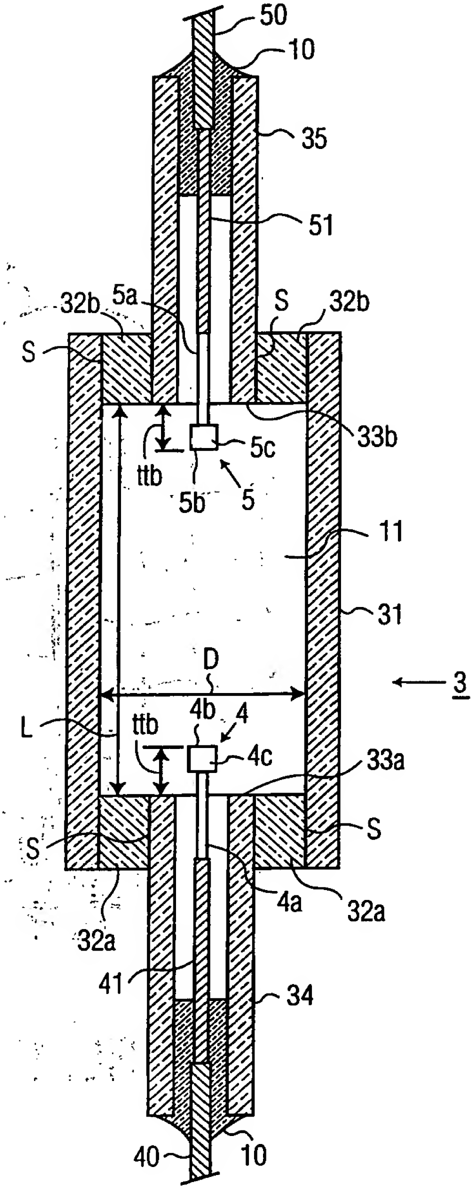


FIG. 1



50
10
35
51
32b
5a
S
32b
S
33b
5c
ttb
5b
5
11
31
D
3
L
ttb
4b
4
4c
33a
S
S
4a
32a
32a
41
34
40
10

FIG. 2

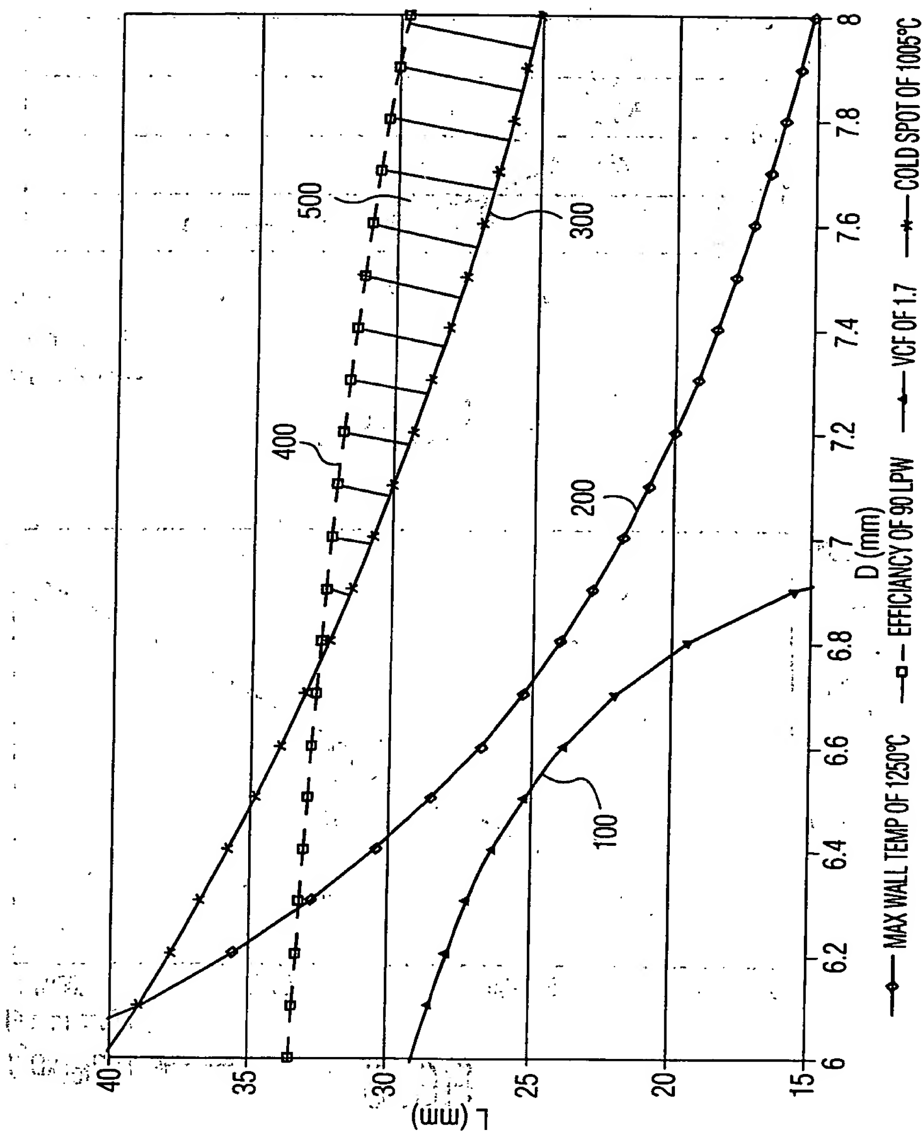

L (mm)
40
35
30
25
20
15
6
6.2
6.4
6.6
6.8
7
7.2
7.4
7.6
7.8
8
D (mm)
100
200
300
400
500
MAX WALL TEMP OF 1250°C
EFFICIANCY OF 90 LPW
VCF OF 1.7
COLD SPOT OF 1005°C

FIG. 3

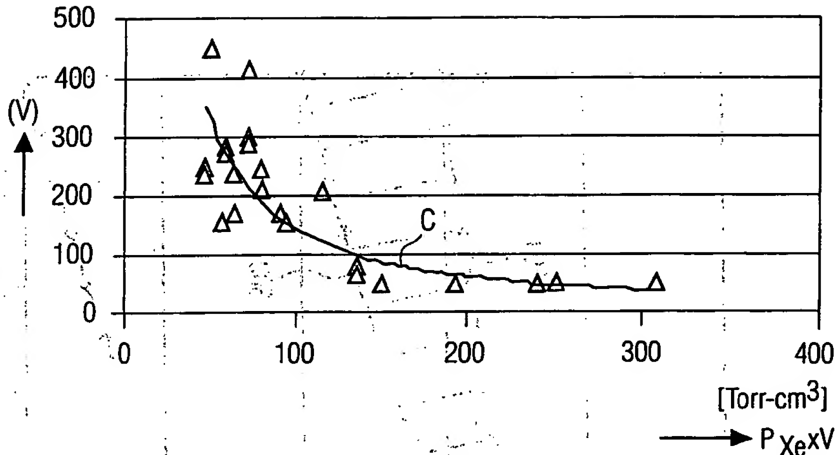

500
400
300
200
100
0
(V)
C
0
100
200
300
400
[Torr-cm3]
P XexV

FIG. 4

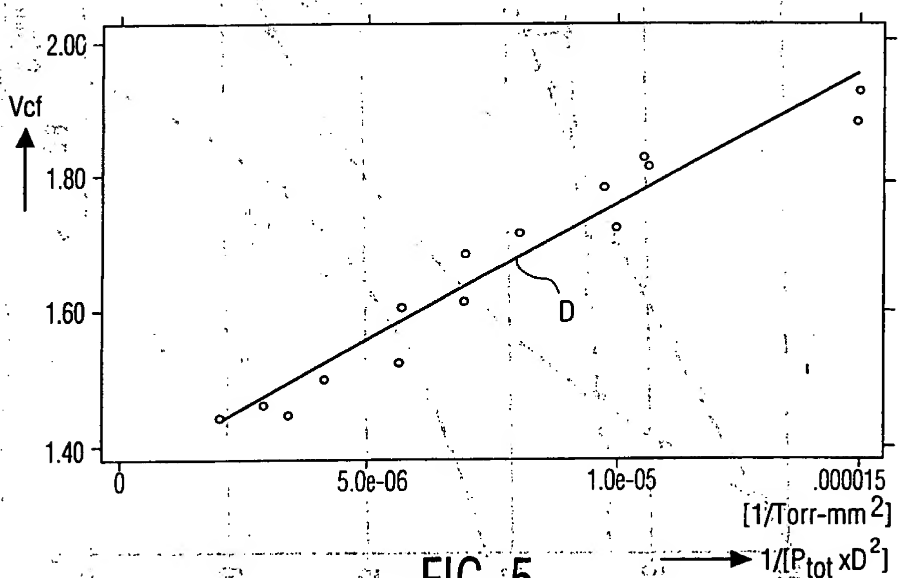

2.00
1.80
1.60
1.40
Vcf
D
0
5.0e-06
1.0e-05
.000015
[1/Torr-mm 2]
1/[Ptot xD 2]

FIG. 5

WATTS	D (mm)	L (mm)	Hg(mg)	Pxe Torr	WALL THK.(mm)	Vcf	ttb,mm	Lm/W	CRI	CCT,K	MPCD
200	7.4	30	2.8	200	0.8	1.4	2	91	88	4340	8.7
200	7.4	26	2.9	200	0.95	1.5	2	91	92	4200	0
400	9.2	40	3.8	100	1.1	1.5	3	95	96	4150	0

FIG. 6

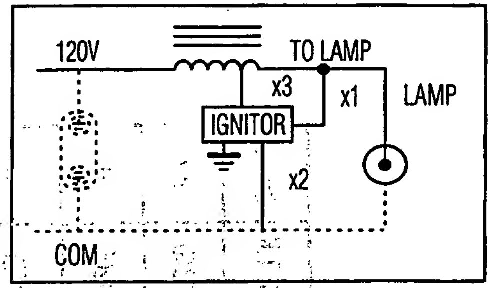


FIG. 7A

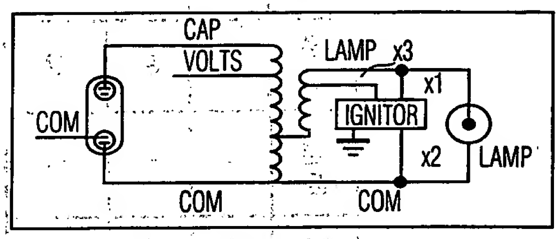


FIG. 7B

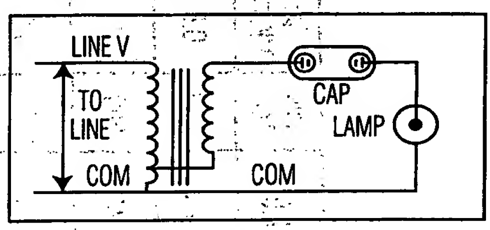


FIG. 7C

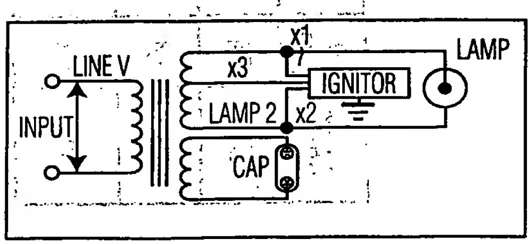


FIG. 7D

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 01/02645

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01J61/82 H01J61/30 H01J61/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 409 517 A (VAN DER SANDE JOHANNES H M ET AL) 11 October 1983 (1983-10-11) cited in the application abstract; claim 1; figure 1 column 4, line 23 - line 33	1
A	US 5 973 453 A (GEIJTENBEEK JOHANNES J F ET AL) 26 October 1999 (1999-10-26) cited in the application abstract; figures column 1, line 31 - line 41 column 5, line 1 - line 31	1

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 July 2001	06/08/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Martin Vicente, M

1

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 01/02645

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 031 332 A (WIJENBERG CHRISTOFFEL ET AL) 29 February 2000 (2000-02-29) cited in the application abstract; claim 1; figures column 1, line 1 - line 10 column 1, line 31 - line 35 column 4, line 5 - line 14 column 4, line 34 - line 36	1
P,A	US 6 172 462 B1 (CARLETON SAMUEL A ET AL) 9 January 2001 (2001-01-09) column 2, line 54 - line 67; figures 1,2 column 3, line 28 - line 32	1

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 01/02645

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